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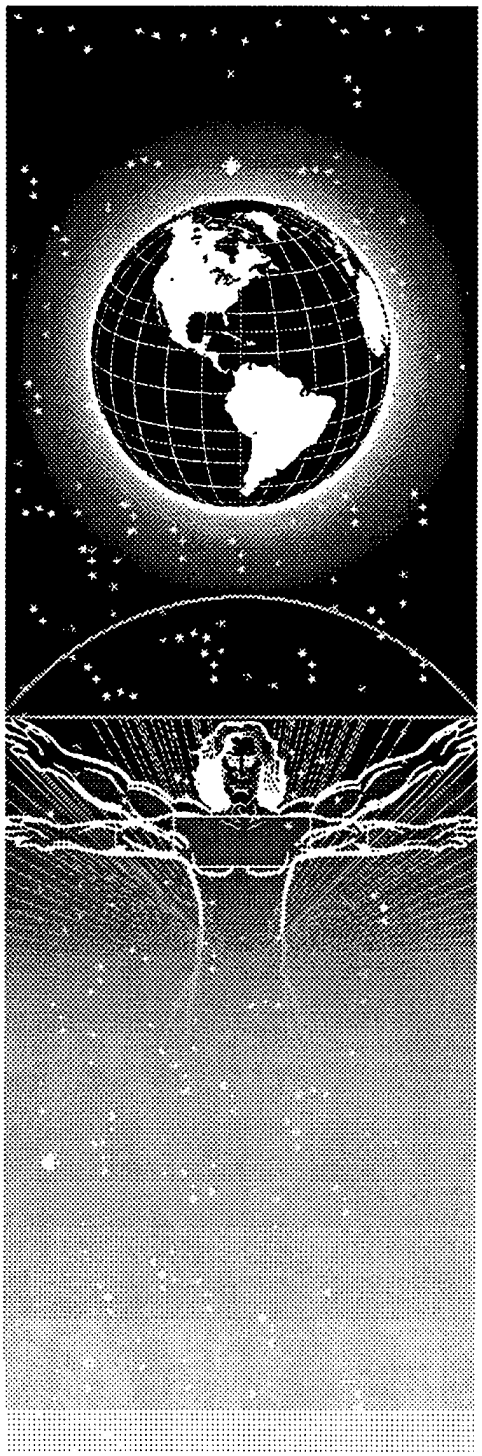

UNITED STATES AIR FORCE
ARMSTRONG LABORATORY

3-Dimensional Audio Ergonomic Improvement Project for the NORAD CMOC

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May 1997

Interim Report for the Period January 1997 to April 1997

Approved for public release; distribution is unlimited.

Crew Systems Directorate
Biodynamics and
Biocommunications Division
Wright-Patterson AFB OH
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This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

Lt Col, Deputy

THOMAS J. MOORE, Chief
Biodynamics and Biocommunications Division
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Armstrong Laboratory

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13. ABSTRACT ***(Maximum 200 Words)***

This technical report describes the concept, design, development, and on-site evaluation of a 3-dimensional (3-D) audio interface system for potential operational use by North American Aerospace Defense (NORAD). An initial prototype phase was used to evaluate the 3-D audio interface system in an operational exercise setting giving NORAD operators the capability to conduct hands-free communication over multiple communication lines. This 3-D audio interface system enabled hands-free communications by providing a headset with 3-D audio capabilities, a boom microphone, and a push-to-talk foot-switch pedal. The 3-D audio interface system provided the sound from the three communication lines to be perceived as coming from three different spatial locations around the operator. The formal evaluation of the 3-D audio systems was accomplished during a Ballistic Missile Defense Organization (BMDO) exercise in late April 1997. This exercise provided an excellent opportunity for a complete evaluation of the functionality and operability of the 3-D audio prototype systems. Results of the evaluation, supplemented by operator responses to a feedback questionnaire, guided the design of the final operational version of the 3-D audio interface system that is to be installed in the NORAD Command Center. The report describes the 3-D audio system integration, the concept of operation, and the results of the exercise evaluation. This project was a cooperative effort between Armstrong Laboratory, Air Force Space Command, and NORAD.

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Executive Summary

This report describes the concept, design, development, and on-site evaluation of the Armstrong Laboratory/Systems Research Laboratories 3-dimensional (3-D) audio interface system that provided North American Aerospace Defense (NORAD) operators with enhanced capability to conduct hands-free communication over multiple communication lines. The results of an on-site evaluation, conducted during an actual exercise and supplemented by operator responses to a feedback questionnaire, provide guidelines for the final design of the 3-D audio interface system for the NORAD Cheyenne Mountain Operations Center (CMOC). This project, a cooperative effort between Armstrong Laboratory, Air Force Space Command, and NORAD, was a huge success and the responses received from those who experienced 3-D audio were very positive. NORAD elected to proceed with this project and asked Armstrong Laboratory to furnish them with six systems for operational use in the Command Center.

Preface

This work was performed by the personnel of the Crew Systems Directorate, Biodynamics and Biocommunications Division, Biocommunications and Bioacoustics Branch, at Wright-Patterson Air Force Base, Ohio. The Armstrong Laboratory is headquartered at Brooks Air Force Base, Texas. Funding for this work was provided by Air Force Space Command, Peterson Air Force Base, Colorado.

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INTRODUCTION

Voice communications continue to be vital to the successful and timely operation of command and control centers around the world. Operators in the North American Aerospace Defense (NORAD) command center currently perform simultaneous voice communications using three independent telephone systems. This concurrent communications requirement creates a juggling nightmare as the operator attempts to simultaneously manage two telephone handsets and one speaker phone or three handsets. These types of human-factors-related difficulties increase the already very high workload created by the events that generate the concurrent communications requirements. This increased workload and the difficulty in interpreting the messages from the independent sources impede the efficiency and effectiveness of the NORAD command center personnel.

The Armstrong Laboratory, the "Human Centered" laboratory, was invited by NORAD to investigate human factors issues at the command center and to recommend changes in procedures and systems to improve the effectiveness of the staff and operations at the center. During this initial fact-finding visit, the Armstrong Laboratory demonstrated a new technology, 3-D audio, which had the potential to resolve the multi-instrument human factors difficulties and improve the communications effectiveness for the command center operators. The demonstration was well received and was the genesis of this project.

BACKGROUND

In 1980, the Armstrong Laboratory (then known as the Air Force Aerospace Medical Research Laboratory) was asked to evaluate the NORAD Missile Warning Center systems and environment as they related to, or possibly impacted, crew performance. This human factors study resulted in a redesign of the command center and the re-allocation of several functions within the center. Several communications-related issues were identified. Some of the issues were addressed with the technology and procedures of the time but several others were left unchanged due to the absence of suitable solutions.

In 1985 Armstrong Laboratory began the development of a unique new technology called 3-D audio. This technology allows users wearing headsets to perceive sounds as originating

from various points in space around the listener. This capability was demonstrated in a laboratory setting in 1987 and a series of experiments in the early 90's (Ericson, et.al., 1997) showed significant enhancements to communications capabilities, especially in multi-channel communications environments when using this technology. The potential application to the NORAD type of command and control communications environment is obvious.

During the 16 years following the initial NORAD study, Armstrong Laboratory researchers and NORAD representatives worked together on three separate surveys to find ways in which to improve the working conditions for the NORAD crew members and thereby improve their mission effectiveness. In addition to these surveys, a guide was developed by the laboratory that provided an overview of the issues and choices in the design of audio communications for C^3 centers (AAMRL-TR-86-018).

The most recent Armstrong Laboratory/NORAD interaction project began in late 1996 and dealt with a wide range of human factors issues including visual display formats, visual display symbology, and the inter- and intra-communication interfaces. The multi-channel communications issues were the same as they had been in the 1980's. During the initial phases of the 1996 effort, the concept of 3-D audio was demonstrated to CMOC crews. Adoption of 3-D audio by these crews had to overcome two major obstacles: the use of headsets and a suitable operator-system interface. A major push toward achieving an ergonomic improvement was to provide the CMOC crews with the ability to conduct hands-free communications operations. The Armstrong Laboratory researchers and the Air Force Space Command's Communications Squadron (AFSPC/CSS) identified headset configurations that might accomplish this objective. The most advanced and forward-thinking of these options was the 3-D audio interface system that spatially separated the inputs coming from multiple communications lines. This 3-D audio interface system allowed operators to function in a hands-free communications environment by providing a headset with 3-D audio capabilities, a boom microphone, and a push-to-talk foot-switch pedal. The 3-D audio interface system enabled the sound from the three communication lines to be perceived as coming from three different locations around the operator, providing the potential to significantly enhance the performance of each operator. The introduction of the 3-D audio headset system enabled the operators to monitor three differently located telephone communications, speak to whichever end user they

selected, and control when they were transmitting with the use of a push-to-talk foot-switch pedal.

NORAD pursued the 3-D audio option. An initial prototype phase was implemented because this was a new application for both the NORAD crews who work in the Cheyenne Mountain Operations Center (CMOC) and the 3-D audio designers. The prototype phase insured the design of an acceptable final product that would meet the requirements of the CMOC crews. The prototype phase provided the CMOC crews the opportunity to use the prototype 3-D audio systems during an actual exercise, enabling them to fully evaluate the usefulness of its capabilities.

There were three major constraints for this project: compatibility, funding, and space. The first major hurdle was interface compatibility. It was essential that the prototype audio systems be compatible with the current CMOC equipment and the red/black isolator control box, which linked the existing systems installed in the CMOC with the prototype units. This portion of the project was worked in cooperation with Kaman Sciences Corporation of Colorado Springs who developed the isolator control box. The isolator unit ensures that classified and unclassified conversations could not occur simultaneously. Another constraint was funding. Although the basic technology for this project was first demonstrated in 1987, this particular application introduced some new and challenging complications. This made it difficult to pinpoint the actual costs of the prototype units needed to meet all of the requirements imposed by NORAD. The available space in the CMOC area for additional equipment is very limited. Due to this constraint, size was a principal concern as the prototypes were designed and fabricated.

OBJECTIVES / APPROACH

The objective of this study was to investigate which configuration of the 3-D audio interface system, if any, could best enhance the NORAD CMOC operational communications. The approach was to construct and install two different prototype configurations of the 3-D audio system by modifying existing 3-D audio signal generation units and augmenting them with additional equipment. Crew performance with their telephone handsets and with each of the prototype audio systems was compared during exercise conditions. Feedback on the performance

of these systems was provided by the various crew members. The 3-D audio systems were evaluated according to the personal preferences of the NORAD Command Center personnel. The relative effectiveness of operations during utilization of the 3-D audio systems was compared to the effectiveness of operations without them. Accomplishment of the evaluation during a Ballistic Missile Defense Organization (BMDO) exercise enabled a complete evaluation of the notable improvements in the operational performance due to the use of the 3-D audio capabilities.

METHOD

Subjective Evaluation Procedure

The formal evaluation of the 3-D audio systems was conducted during a Ballistic Missile Defense Organization (BMDO) exercise in late April 1997. The exercise was a five-day, full-blown training scenario that enabled the CMOC crews to evaluate the functionality and operability of the prototype systems. Operators processed a variety of inputs from multiple sources using the 3-D audio systems in a high stress, low risk environment. During and after the BMDO exercise, questionnaires (Appendix A) were filled out by all users to provide feedback on their personal preferences and on the operational effectiveness of the 3-D audio system as well as on the three individual headset system configurations. In addition to the use of the systems during various time segments of this five-day exercise, the systems were used during the two-week training period prior to the exercise.

Equipment

The equipment used for this prototype phase involved two 3-D audio signal generator systems modified to meet the integration needs of the NORAD Cheyenne Mountain Training Simulator (CMTS) station. These 3-D prototype systems were designed and fabricated using a combination of on-hand equipment and newly purchased equipment. The Audio Interface Controller Unit and the Transmit Selector Panel are pictured in Figures 1 and 2. A schema of the integrated 3-D audio system showing the input/output channels is displayed in Figure 3. The

listening channel consisted of the phone inputs through the 3-D generator to the operator's headset. The output channel consisted of the push-to-talk switch-controlled microphone through the isolator unit to the phones. The destinations of the outputs were selected by the operator with the Transmit Selector Panel.

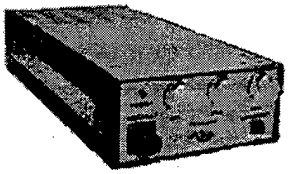

Figure 1. Audio Interface Controller Unit

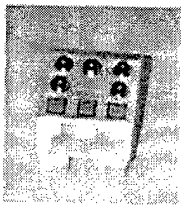

Figure 2. Transmit Selector Panel

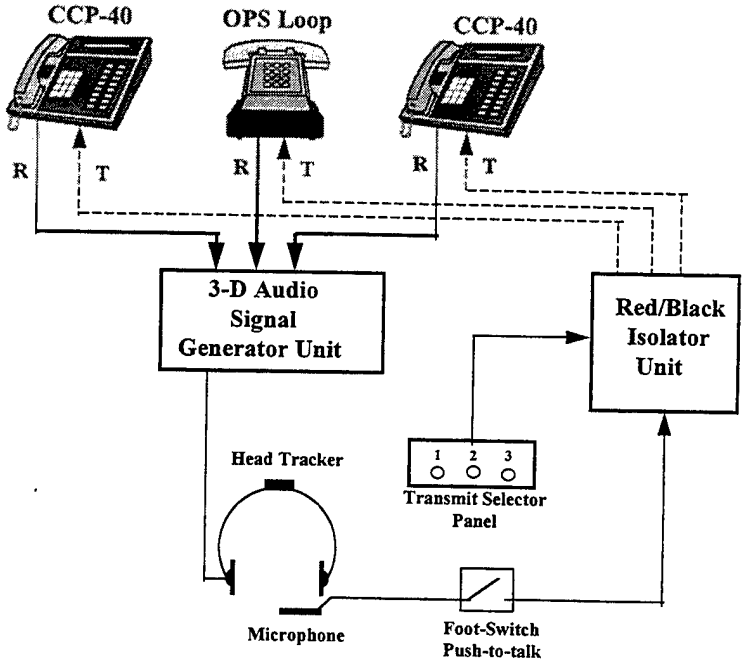

Figure 3. CMOC 3-D Headset Set-Up

The head-tracking systems were purchased through three different suppliers to allow Armstrong Laboratory and NORAD to evaluate which type of system would be the best for this project based on functionality and operability. The head-tracking systems were integrated with the 3-D audio signal generation systems to enable Armstrong Laboratory to satisfy the requirements set forth by NORAD and AFSPC/CSS.

Facilities

The 3-D audio prototype systems were installed at the Cheyenne Mountain Training Simulator (CMTS) station located at Falcon Air Force Base, Colorado. These prototype systems, along with three configurations of the headset design (Figure 4), were installed and evaluated by NORAD Command Center personnel during the BMDO exercise. Although the CMOC is where the 3-D audio systems are ultimately to be installed and operationally used, it was not accessible. The CMTS provided a suitable alternate location at which the test and evaluation of these prototype systems were accomplished. The basic layout of the NORAD Command Center and the CMTS facility is shown in Figure 5.

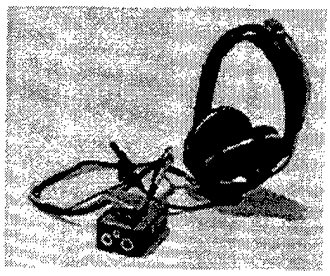

Figure 4. Prototype Headset Design

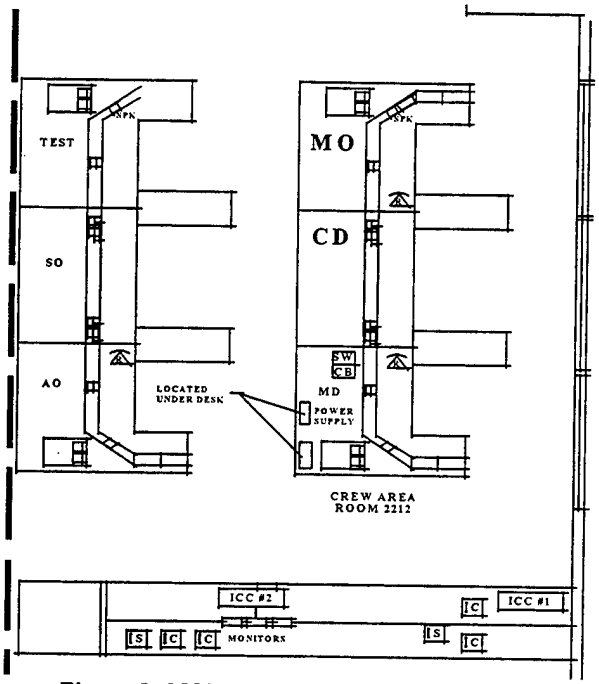

Figure 5. NORAD Command Center Layout

Two positions, the Command Director (CD) and the Mission Operator (MO), were equipped with the 3-D audio prototypes during this prototype phase. This allowed both positions to simultaneously use and evaluate the full range of capabilities provided by these systems. After the initial installation and checkout of the systems, the AFSPC/CSS Points of Contact (POCs)

were trained on the general operational procedures (Appendix B), basic troubleshooting, and the procedures for interchanging the three headset systems used during this phase. These POCs were then responsible for the system demonstrations to the NORAD crew members.

Functionality and Operational Procedures

Both of the 3-D audio prototype systems functioned the same. The red/black isolator unit physically separated the receive and transmit lines to avoid crosstalk. The receive lines were from two CCP-40 phones and one direct operations line. These lines fed directly into the 3-D audio signal generator unit. This unit generated the spatial separation the user hears among the three conversations. From there, the receive lines fed into a 3-D audio interface controller unit which combined the lines into one while maintaining the 3-D effect. This unit allowed the user to individually adjust the volume level of each signal. The 3-D audio controller unit also received an input from the head-tracking unit and the head-tracking source. These two units allowed the 3-D audio controller unit to keep track of the exact location of the user's head and to continuously adjust the 3-D spatial separation effect accordingly. The combined signal was fed directly to the headset where the user could listen to one, two or three conversations simultaneously. The conversations were perceived to come from 90° to the right, 90° to the left, and directly in front of the operator. The virtual locations of the conversations remained fixed at these locations and did not change with the head movements of the operators.

The controlling of the voice output from the microphone was accomplished with the red/black isolator unit. The red/black isolator unit ensured that classified and unclassified communications were not mixed. This was accomplished with logic circuitry that physically prevented transmission of classified communication over unclassified lines. The user could choose to transmit or receive over one, two, or all three of the phone lines by pressing the corresponding buttons on the transmit selector panel which fed into the red/black isolator unit. The transmit selector panel also has two lights above each button. These buttons indicate whether the call being answered/placed was classified (red light) or unclassified (blue light). In the event of a potential security violation, the logic circuitry prevented the selector button from being engaged and caused a warning tone to be emitted over the headset. In addition to this logic

circuitry barrier, a push-to-talk foot-switch pedal acted as an input to the red/black isolator unit. All transmissions were completely blocked unless the foot-switch was pressed.

During the BMDO exercise the operators worked in an environment requiring the manipulation of three separate phone communication devices. The operators wore one of the three 3-D audio headsets and evaluated how the system enhanced or hindered the effectiveness in accomplishing the job. Each headset incorporated a different head-tracking device with a slightly different configuration. The first headset was configured with a large beltpack which contained all of the electronics for the head-tracking system. The second headset was configured with a smaller beltpack which allowed for a quick disconnect from the system. The final headset had a belt clip but did not have a beltpack. These configurations enabled the operators to experiment with each setup and determine which best met the job requirements. The three headset systems also enabled the operators to evaluate three different head-tracking devices.

Subjective Evaluation Participants

The participants for this project were the CMOC operators. Members of the CMTS staff were also given a demonstration of the system which enabled them to provide additional inputs to the design of the final 3-D audio system to be developed for use in the NORAD CMOC.

The AFSPC POCs conducted the demonstrations and assisted NORAD CMOC crew members with the operational procedures of the 3-D audio prototype system during the evaluation period. As time allowed, they obtained completed questionnaires from the participants. After the exercise, they collected the inputs and recorded the list of feedback comments.

DATA

During the demonstrations and BMDO exercise the systems were evaluated and a thorough checkout of their functionality was completed. Overall, the use of the 3-D audio interface system was well accepted. Feedback (Appendix C) was received through the use of questionnaires. The consolidated feedback comments received from the operators are listed in Figure 6. Four major findings emerged from the questionnaires and comments of the command center operators. First, a fourth communication channel is required to allow for an STU III line.

Second, a push-to-talk switch on the belt is desired in addition to the foot-switch push-to-talk pedal. Third, the performance of the three different head-tracking systems was very similar. Fourth, a beltpack was not a desired configuration design for the final product. Other feedback was analyzed for feasibility then weighed against conflicting feedback.

Position	Comment
CO:	- The sound quality is high (Bose like) - The biggest problem during high volume/stress scenarios was the transmit select needs to be on or near desk top level - Didn't need to write things down during recap since his hands were free - Would like transmit selector buttons on 'left' on or near desk top (the left hand is 'freer' than the right) - Wants PTT switch fixed to floor on right side near cabinet so his boot can find it more easily - Best concept he's used
MO:	- Option to put PTT on belt or on foot switch with toggle on volume control box - Longer cord for MO position - Bolt foot switch to floor
CMOC/ J3T:	- Sanitary concerns - each crew member needs to be issued their own headset - Locking mechanism for the boom mic - Smaller mic - Quick release for walkaway (canon plug) - Transmit selector built-in (not on desk top) - Ruggedized fall back plugs
Other:	- IR option is viable to eliminate cords all together - Need to have a data to have units to the field for the Generals - The operators still have to take OPs loop phone on and off hook to answer/terminate

General Comments:

About the addition of a fourth channel - The 3-D headsets must include the STU-III as a fourth channel. Without this feature, the operator will not have a hands-free environment, defeating the purpose of the 3-D headset effort. We understand that the headsets cannot determine at what classification the STU-III is operating, and that we therefore may not be able to transmit simultaneously on the STU-III and other phones because of possible security violations. Request you investigate if the security logic could be designed such that users can be prevented from talking simultaneously on the STU and any other lines. This way, no matter what security level the STU-III is operating at, no security violation can occur.

About the keychain devices - The CD's haven't really noticed them too much since they have remained seated for most the demo's. When we showed them, most thought it was 'neat.' The MO's (one in particular) have moved around a little more so they have noticed them. When one of them 'tested' its limits he concluded that it was good since it would stretch farther than the glass wall in the real CMOC would allow him to move. One of the MO's gave us the requirement for a longer cord so he could walk around the side of the console to do classified work.

About the Size/Weight of the Sensors - Only one person so far has made any comments about the weight of the headsets at all, and not specifically about the sensors. He said that after wearing the sets for 'a few hours' they would most likely feel heavy and a little hot. He then said crews might resist if they are 'forced' to wear them on an everyday, continuous basis. We told him we were not going to 'mandate' their use to the crews and they could take them off and on at their convenience.

About the Belt Pack/ Quick Disconnect - Some conflicting feedback here. Some didn't like a "heavy" belt pack and would like none at all. All liked the idea of a one connector quick disconnect. One group wanted to have a PTT switch on the belt pack in addition to the floor mounted PPT so they could transmit while standing away from the console. Once we get more feedback from more people we will figure out which way the majority of the crews may want to go.

About the final product - AFSPC fund 6 headsets (one for the MO, MD, AO, and CD positions plus spares). Ensure the units are sanitary -- perhaps have separate microphone booms for each operator, or provide crew members with separate foam covers for the microphones.

Figure 6. Comments from the Questionnaires as Consolidated by the NORAD CMOC Systems Integration Personnel

DISCUSSION

The demonstrations and evaluations of the 3-D audio system modified for NORAD CMOC operations were very successful. Operators liked the capability of having their hands

free during communications, enabling them to perform other tasks. They were also impressed with the ease with which they could distinguish the different phone conversations. One operator was observed turning his head to "look" at the virtual location of the individual with whom he was communicating, as if they were sitting side-by-side. This is a clear illustration of the effectiveness of the 3-D audio and the enhanced perception experienced by the operators.

The head-tracking systems attached to each headset were different; however, performance was determined to be equivalent or essentially the same. Selection of the headset head-tracking system was based on optimum size and cost per system. The unit without the beltpack was chosen. The belt clip was endorsed as eliminating the added weight and obstruction of an actual beltpack.

The prototype phase of this project was very informative and provided a variety of different feedback responses to Armstrong Laboratory, both in the use of 3-D audio systems and in the area of user requirements. The acquired experience and information obtained from the demonstrations and exercise, and the interactions with numerous NORAD personnel, have provided excellent guidance for final system design. This informed use of the technology, as well as the requirements and desires of the operational personnel, greatly enhances the assurance that the final product will be a significant upgrade of the system that will enable increased operational communications effectiveness.

SUMMARY

This project was a huge success and the responses received from those who experienced 3-D audio were very positive. NORAD elected to proceed with this project and asked Armstrong Laboratory to furnish them with six systems for operational use in the Command Center. To do this, the 3-D audio designers will seek to miniaturize the 3-D audio system components while maintaining and improving system capabilities. After the first version of this final system is designed and built, it will be tested by AFSPC personnel. Armstrong Laboratory will perform any needed modifications to obtain the required certification of this product prior to proceeding with the fabrication of the additional systems. Four of the units will then be installed in the CMOC while the remaining two units will serve as spares.

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Appendix A

3-D AUDIO QUESTIONNAIRE

3-D AUDIO QUESTIONNAIRE

INTRODUCTION: Please use this form to evaluate the 3-D audio concept for use in the Cheyenne Mountain Operations Center. The units presented here are prototypes and offer three different types of headsets. Accurate input is essential to providing the operator the best possible final product. Thank you for your time.

Headset Unit Number: _____

DIRECTIONS: Please circle the appropriate response(s):

I. Headset:

1. While wearing the headsets, I could
A. hear room conversation just fine.
B. barely hear room conversation.
C. not hear room conversation.

2. The boom microphone
A. enabled me to talk more comfortably than with a phone receiver.
B. allowed me to talk as if I were using a regular phone receiver.
C. forced me to talk louder than I would have normally.

II. Head Tracking System:

3. The overall size and weight of the headset was
A. not a noticeable problem.
B. heavy but not a problem.
C. heavy which made things awkward.

4. The stability of the headset was (fine / awkward / poor).

5. The frequency at which you had to re-boresight the head-tracking system was
A. not a problem and easy to do.
B. an adequate rate but bothersome.
C. too often and time consuming.

6. The head-tracking system performed
A. amazingly, too cool for words.
B. well and it helped keep the communications straight.
C. badly and was confusing to work with; I'm not impressed.

7. The three phone communications (did / did not) remain fixed in space.

III. Belt Attachment:

8. Rate the usefulness of having a beltpack with quick disconnect (for units 1 & 3):

Poor Fair O.K. Good Excellent N/A

9. Do you feel there is a need for a quick disconnect? (yes / no)

10. Rate the cable retracting system for managing the headset cords:

Poor Fair O.K. Good Excellent

IV. Receive Control Panel (blue control panel on shelf):

11. Was the range of the dial adequate for controlling the volume? (yes / no)
12. The boresight button was
A. handy and easy to use.
B. not located in a convenient location.

V. Transmit Control Panel (silver control box with red & blue lights):
13. The control panel buttons were
A. easy to use and conveniently located.
B easy but not conveniently located.
C. difficult to operate but conveniently located.
D. difficult to operate and not conveniently located.

14. Rate the ability to maintain the proper level of security:

Poor Fair O.K. Good Excellent N/A

15. The lights were
A. useful and easy to understand.
B. did not capture my attention as needed.
C. not effective.

VI. Audio Characteristics:
16. The clarity and strength of the incoming calls were
A. clear and understandable.
B. comparable to the old system.
C. less clear than the old system.

17. The audio cue for "boresight" was (beneficial / annoying).

18. The audio cue for "security alert"
A. was adequate to get your attention.
B. did not alert you to the problem.

19. Were the three voice channels located at the positions you desire? (yes / no)

20. Was it easy to distinguish among the three voice channels? (yes / no)

VII. Overall System Performance:
21. The headset was
A. not noticeable after wearing for a time.
B. tolerable.
C. uncomfortable and hampered mobility.

22. Compare intelligibility of 3-D audio system with the individual handset (old system).
A. much better.
B. a little better.
C. the same.
D. worse.

23. Rate the performance of the system for providing hands-free operations.
A. true hands-free operations.
B. partial hands-free operations.
C. no noticeable improvement.
D. more cumbersome.

24. Rate the system for helping the operator meet mission requirements:

Poor Fair O.K. Good Excellent

25. Do you have any other suggestions or comments?

Appendix B

NOTES TO OPERATORS

Notes to Operators

1. Treat the headsets nicely, they're prototypes which basically means they are expensive, delicate, and not easily or quickly replaceable.

2. Keep in mind that the functionality and configuration of these prototypes are two different things. The headset sensor and the beltpack configurations for a final product can be any one of the current configurations for whichever system is preferred based on its functional capabilities.

3. Please fill out the questionnaire to furnish us as much feedback as possible to provide you with the best possible final product.

Thank you for your cooperation!

BELTPACK Configuration Options:

The LSI (Headset #1) and the Polhemus (Headset #3) allow you to disconnect the headset from the blue control panel and wander with the headset still on your head.

LSI (Headset #1) - disconnect military cannon plug and microphone line at the beltpack to enable you to wander with the headset; please ensure that you perform a boresight after reconnecting the military cannon plug and the microphone line.

Polhemus (Headset #3) - disconnect the 3 plugs on the beltpack to enable you to wander with the headset; please perform a boresight once you have re-connected all 3 lines.

3-D Audio System Operating Instructions

Change from normal handset to 3-D audio operation
1. Unplug handset pigtails.
2. Plug in pigtails of 3-D audio systems.

Return to normal handset from 3-D audio operation
1. Unplug pigtails of 3-D audio system.
2. Plug in pigtails of handsets.
3. Power down 3-D audio system components (per checklist steps below).

Power-down Procedures.
1. Turn off the head-tracking system.
2. Turn off 3-D generator box.
3. Turn off transmit switch box power supply.

To perform a boresight:
1. Place finger on boresight button located on the blue control panel box.
2. Face straight ahead with headset on head.
3. Push and release boresight button.
4. Ensure you heard the audio cue (whoop-whoop tone).

To answer incoming CCP-40 phone call
1. Push appropriate line button.
2. Conversion will be presented over headset.

To terminate CCP-40 call
1. Reset appropriate line button OR select another line.

To answer or make an Operations Line call
1. Remove phone receiver from switchhook.
2. Conversation will be presented over headset

To terminate Operations Line call
1. Place phone receiver back on switchhook

To speak to any of the open lines
1. Flip appropriate switch(s) on transmit selector box.
2. Press and hold foot-switch pedal.
3. Speak into microphone.
4. Release foot-switch when finished speaking.

To customize volume levels
1. Adjust volume knobs on blue control panel - clockwise for higher volume.

Hook up LSI system (Headset #1)

1. Ensure InterSense head-tracking system is powered off.
2. Connect 3-D ADG Control Panel Interconnect Cable (Item # 308 or 309) between 3-D generator box (19" rack) and blue control panel box.
3. Connect LSI Interconnect Cable (Item #305) to blue control panel.
4. Connect the other end of the LSI Interconnect Cable to the large beltpack (Item #407).

Hook up InterSense system (Headset #2)

1. Ensure LSI Interconnect Cable (Item #305) has been disconnected.
2. Connect 3-D ADG Control Panel Interconnect Cable (Item # 308 or 309) between 3-D generator box (19" rack) and blue control panel box.
3. Connect Control Panel/Tracker Interconnect Cable (Item #303 or 304) to the blue control panel box and the tracking system box.
4. Connect InterSense Head Tracking System with Cable (Item #302) to blue control panel.

Hook up Polhemus system (Headset #3)

1. Connect 3-D ADG Control Panel Interconnect Cable (Item # 308 or 309) between 3-D generator box (19" rack) and blue control panel box.
2. Connect Control Panel/Tracker Interconnect Cable (Item #303 or 304) to the blue control panel box and the tracking system box.
3. Connect Polhemus Headset Interconnect Cable (Item #301) to blue control panel
4. Connect the other end of the Polhemus Headset Interconnect Cable to small beltpack box (Item #404).

Power-up Procedures for LSI headset (Headset #1).

1. Turn on 3-D generator box located behind the desk.
2. Turn on the transmit switch box power supply located behind the desk.
3. Place headset on head.
4. Boresight the system.

Power-up Procedures for InterSense headset (Headset #2).

1. Place headset on desk.
2. Turn on the InterSense power supply box (located on the shelf).
3. Turn on 3-D generator box (19" rack) located behind the desk.
4. Turn on the transmit switch box power supply located behind the desk.
5. Allow InterSense system to warm up for 20 minutes prior to use.
6. Place headset on head.
7. Boresight the system.

Power-up Procedures for Polhemus headset (Headset #3).

1. Turn on head-tracking system.
2. Turn on 3-D generator box (19" rack) located behind the desk.
3. Turn on the transmit switch box power supply located behind the desk.
4. Place headset on head.
5. Boresight the system.

Troubleshooting

If incoming voice channels drift from the desired position, perform a boresight.

If you cannot hear incoming voice, ensure all connections are securely plugged in.

If the distant end cannot hear you, ensure the foot-switch pedal is securely plugged in and/or ensure foot-switch pedal is fully pressed when you are talking.

If you cannot hear one of the incoming voice channels, check the appropriate volume control dial.

If the distant end cannot hear you, check the microphone position and orientation and/or check to ensure that the appropriate switch for that channel activated.

If all else fails, power down the unit (according the written procedures), wait 3 seconds, then power back up the unit (according to the written procedures).

If none of the above actions corrects the problem, call Dave Ovenshire at DSN 785-3328 or Capt Deb North DSN 785-3671.

Appendix C

CMOC FEEDBACK RESPONSE

3-D AUDIO QUESTIONNAIRE

INTRODUCTION: Please use this form to evaluate the 3-D audio concept for use in the Cheyenne Mountain Operations Center. The units presented here are prototypes and offer three different types of headsets. Accurate input is essential to providing the operator the best possible final product. Thank you for your time.

Headset Unit Number:

DIRECTIONS: Please circle the appropriate response(s):

I. Headset:

1. While wearing the headsets I could
(A) hear room conversion just fine.
B. barely hear room conversion.
C. not hear room conversion.

2. The boom microphone
A. allowed me to talk as if I were using a regular phone receiver.
B. forced me to talk louder than I would have normally.
(C) enabled me to talk more comfortably than with a phone receiver.

II. Head Tracking System:

3. The size and weight of the head tracking sensor attached to the headset was
(A) not a noticeable problem.
B. heavy which made things awkward.
C. heavy but not a problem.

4. The stability of the head tracking sensor was (fine / awkward / poor).

5. The frequency at which you had to re-boresight the head tracking system was
(A) not a problem and easy to do.
B. an adequate rate but bothersome.
C. a pain to remember and time consuming.

6. The head tracking system performed
A. amazing, too cool for words.
(B) well and it helped keep the communications straight.
C. badly and was confusing to work with; I'm not impressed.

7. The three phone communications (did / did not) remain fixed in space.

III. Belt Attachment:

8. Rate the usefulness of having a beltpack with quick disconnect (for units 1 & 3):

Poor Fair O.K. Good Excellent (N/A)

9. Do you feel there is a need for a quick disconnect? (Yes / No)

10. Rate the cable retracting system for managing the headset cords:

Poor Fair (O.K.) Good Excellent

IV. Receive control panel (blue control panel on shelf):

11. Was the range of the dial adequate for controlling the volume? (yes / no)

12. The boresight button was

A. handy and easy to use.
B. not located in a convenient location.

V. Transmit Control Panel (silver control box with red & blue lights):

13. The control panel buttons were
A. easy to use.
B. conveniently located.
C. difficult to operate.

14. Rate the ability to maintain the proper level of security:

Poor Fair O.K. Good Excellent

15. The lights were
A. not effective.
B. useful and easy to understand.
C. did not capture my attention as needed.

VI. Audio Characteristics:

16. The clarity and strength of the incoming calls were
A. clear and understandable.
B. comparable to the old system.
C. less clear than the old system.

17. The audio cue for "boresight" was (annoying beneficial).

18. The audio cue for "security alert"
A. was adequate to get your attention.
B. did not alert you to the problem.

> don't remember it

19. Were the three voice channels located at the positions you desire? (yes no)

20. Was it easy to distinguish between the three voice channels? (yes no)

VII. Overall System Performance:

21. The headset was
A. not noticeable after wearing for a time.
B. tolerable (+)
C. uncomfortable and hampered mobility.

22. Compare intelligibility of 3-D audio system with the individual handset (old system)
A. much better.
B. a little better. (+)
C. the same.
D. worse.

23. Rate the performance of the system for providing hands-free operations.
A. true hands-free operation.
B. partial hands-free operation.
C. no noticeable improvement.
D. more cumbersome.

24. Rate the system for helping the operator meet mission requirements:

Poor Fair O.K. Good Excellent

- THE SOUND QUALITY IS HIGH (BOSE-LIKE)
- TRANSMIT SELECTOR NEEDS TO BE ON/NEAR DESKTOP LEVEL
- DIDN'T NEED TO WRITE THINGS DOWN DURING BEEP SINCE the HANDS were FREE
- WOULD LIKE TRANSMIT SELECTOR BUTTONS ON "LEFT", ON OR NEAR DESKTOP. (THE LEFT HAND IS 'FREER' THAN RIGHT HAND.)
- WANTS PTT SWITCH FIXED TO FLOOR ON RIGHT SIDE NEAR CABINET SO HIS FOOT CAN FIND IT MORE EASILY

→ biggest problem during high volume/stress scenario

- Best concept I've used